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Publication date:
2013

Citation (APA):
Hahmann, A. N., Casso, P., Campmany, E., Vincent, C. L., Kelly, M. C., Badger, J., Moreno, P., & Ejsing Jørgensen, H. (2013). *Towards a generalization procedure for WRF mesoscale wind climatologies*. Poster session presented at European Wind Energy Conference & Exhibition 2013, Vienna, Austria. http://www.ewea.org/annual2013/

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TOWARDS A GENERALIZATION PROCEDURE FOR WRF MESOSCALE WIND CLIMATOLOGIES

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Abstract

We present a method for generalizing wind climatologies generated from mesoscale model output (e.g. the Weather, Research and Forecasting (WRF) model.) The generalization procedure is based on Wind Atlas framework of WAsP and KAMM/WAsP, and been extensively in wind resources assessment in DTU Wind Energy for many years (Mortensen et al 2005, Badger et al 2010).

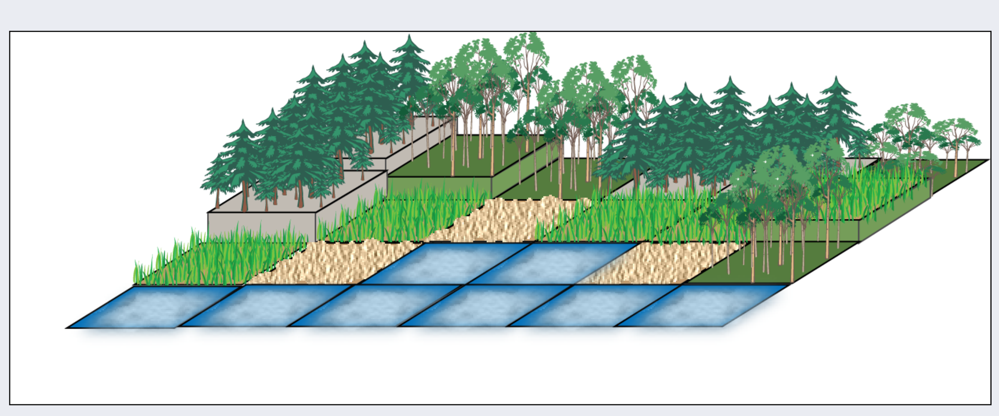
The method is verified by two distinct sets of WRF simulations: A single WRF wind atlas over Denmark, and a series of WRF simulations with the Vortex MAPS system with 29 sites in many wind climate regimes.

Comparison is made between generalized wind climatologies estimated by the microscale model WAsP and the methodology presented here. For the Danish wind measurements the mean absolute error in the ‘raw’ wind speeds is 9.2%, while the mean absolute error in the generalized wind speeds is 4.1%. The generalization procedure has been installed and automated in the Vortex downscaling chain for the MAPS calculation, which are computed at 3 km horizontal resolution grid. For the MAPS-derived wind speeds the mean absolute error in the ‘raw’ wind speeds is 17.3%, while the mean absolute error in the generalized winds is 10.7%.

Motivation

Because wind climatologies extracted from a mesoscale model simulation are spatially averaged values representative for the area of the grid box size (see Figure below), usually of orders of km, they should not be directly compared to those measured at a mast nor used directly as input to a microscale model. In addition, over land there is a need for standardization because the topography and surface roughnesses in a model grid box and in the surrounding grid boxes are often very different from those around the site where measurements were taken, especially in complex terrain.

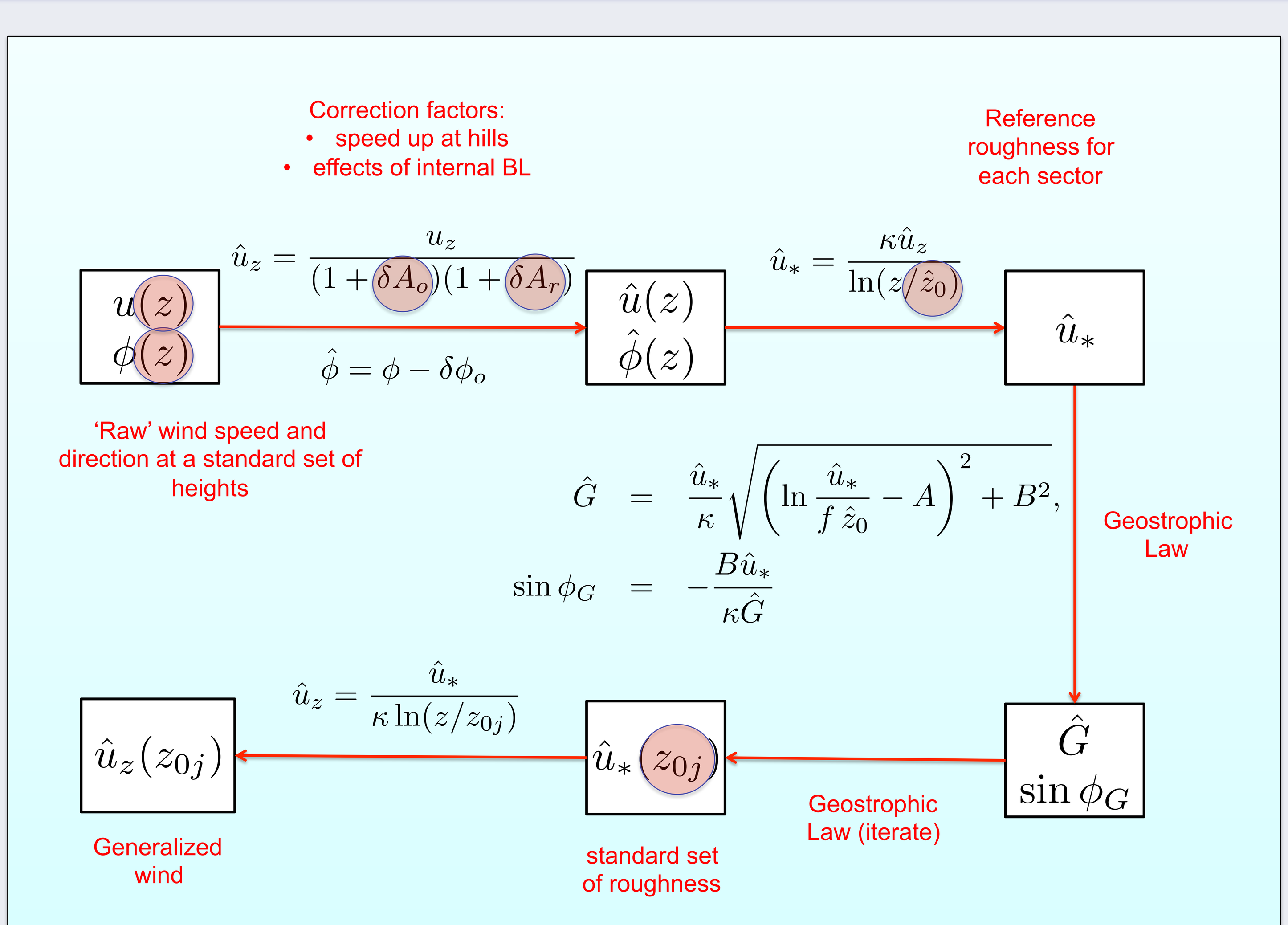
Nature



WRF model view of nature

One big advantage of the generalized wind climate approach is that it allows for the mesoscale wind climate to be downscaled further via microscale models. By removing mesoscale effects such as the topographic speed up, they are not double counted when coupling to a microscale model.

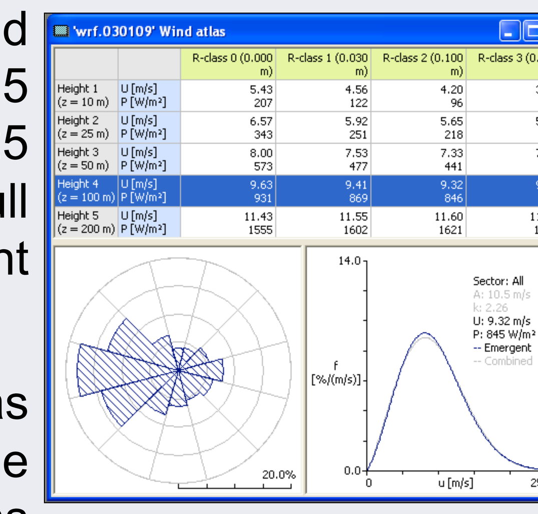
Method



A diagram of the procedure used to generalize winds derived from the output of mesoscale models is shown above. Time series of wind speed and direction are computed from the WRF model output at a set of standard heights (e.g. 10, 25, 50, 100 and 200 m AGL) are generalized to a standard set of roughness (z_0=0.0002, 0.03, 0.1, 0.4, 1.5 m)

The generalization is based on removing the speed-up effects due to mesoscale orography (e.g. speed-up at hills) and roughness change (e.g. the effects of the internal boundary layer along the coastline) and the upstream reference roughness for each sector surounding the mesoscale model grid point.

Therefore, from the original time series of wind speed and direction at each standard level, 25 (i.e., 5 heights and 5 roughness lengths) time series are generated. The 25 time series are then statistically represented via a Weibull fit for each wind direction sector. The figure on the right shows the structure of the resulting WAsP "lib" file.



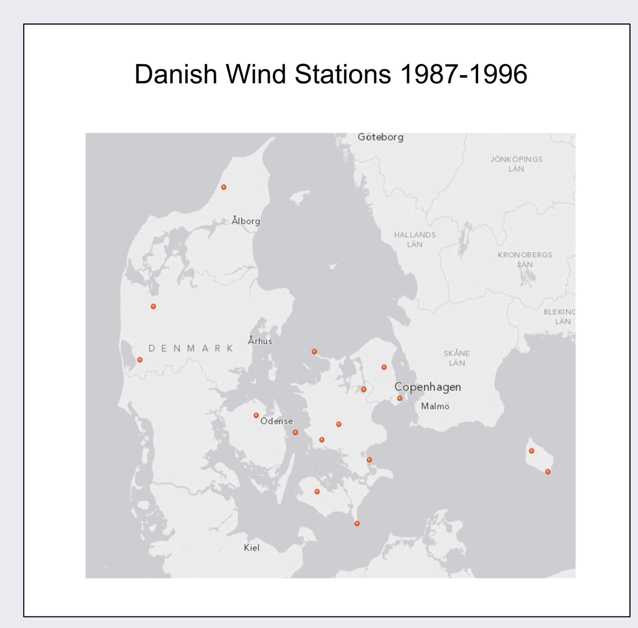
The generalization procedure is further described and has been used in Lársen et al. (2012) for estimating extreme winds, in Tammelin et al. (2013) for the Finish Wind Atlas and in Hahmann et al. (2012) in the Wind Atlas of the Baltic Seas.

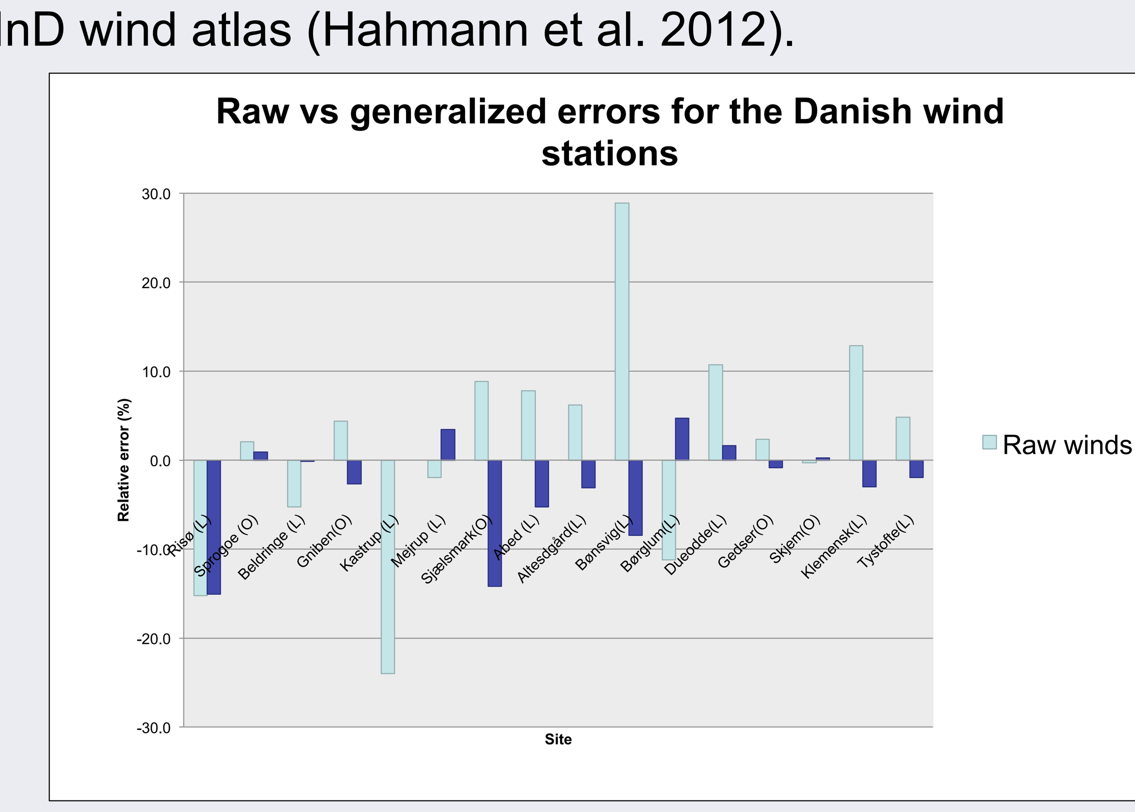
Results

Example 1. Danish Wind Stations

The wind climate estimated from a network of surface stations (see map down and left) covering Denmark is compared to the wind climate estimated from WRF analysis simulations (5 km grid spacing, 2006-2011) created for the North and Baltic Seas in the NORSEWInD wind atlas (Hahmann et al. 2012).

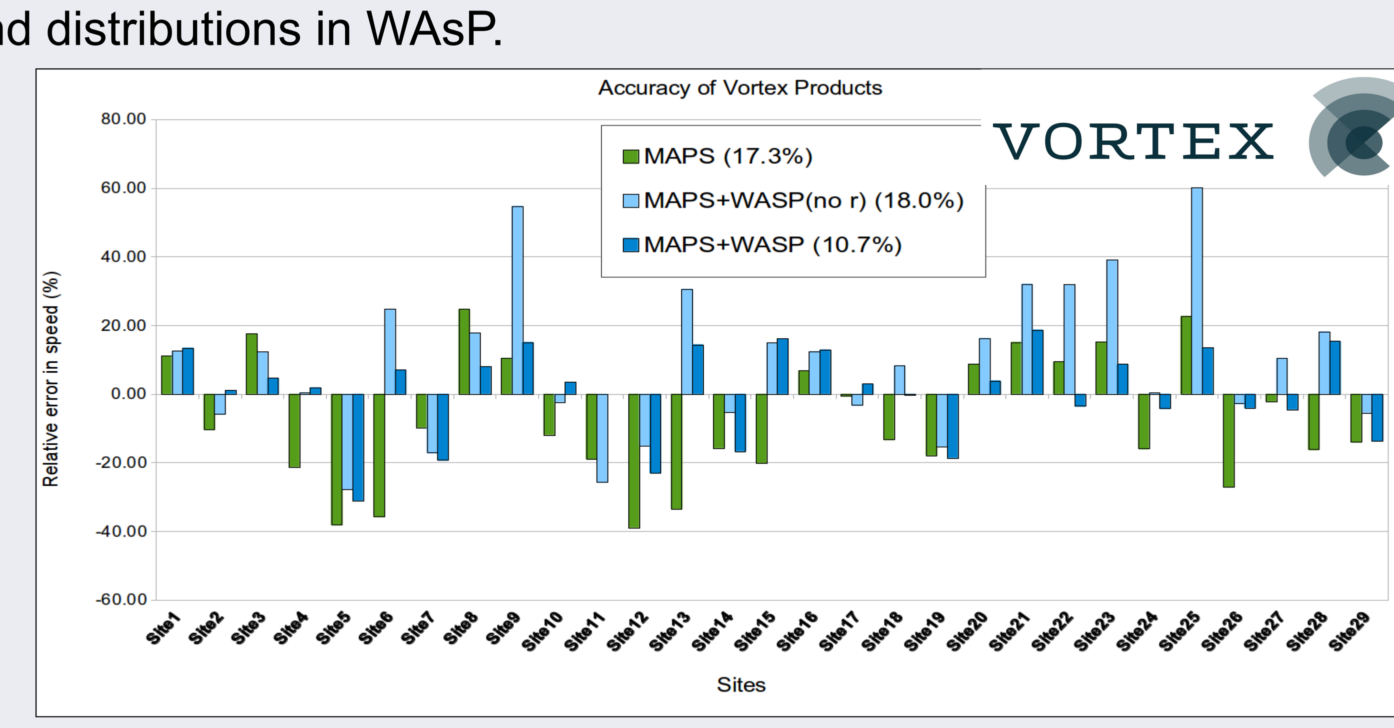
$$Err = \frac{(\overline{U}_{obs} - \overline{U}_{WRF})}{\overline{U}_{obs}}$$





Example 2. Vortex MAPS system simulations

The analysis was performed for 29 sites located across Europe, North America, South Africa, South America and Australia. The studied locations show very different characteristics such as complex terrain, coastal sites, forest or semi-desert areas. The WRF mesoscale model was run at a final horizontal resolution of 3km and generalization of the wind was performed for each time step of the model output. SRTM topography and ESA landuse globcover was used for downscaling the wind distributions in WAsP.



Conclusions

Up to now, the generalization procedure has been applied to mesoscale model simulations using the Karlsruhe Atmospheric Mesoscale Model (KAMM) and to observations using WAsP. DTU Wind Energy is in the process of adapting the procedure to simulations using the Weather Research and Forecasting (WRF) model. The initial results presented above are encouraging but further work is needed because the diffusive characteristics in the WRF model, which define the model's effective resolution, are different from those in the KAMM model.

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